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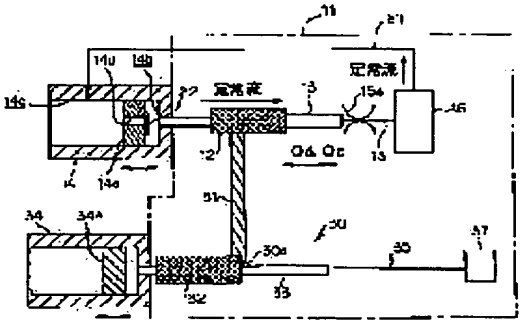
(54) PULSE TUBE REFRIGERATING MACHINE

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a small and lightweight pulse tube refrigerating machine in which refrigerating capacity is enhanced while simplifying the structure by reducing heat flowing unnecessarily into a low temperature part through heat transfer in a cold accumulator.
SOLUTION: The pulse tube refrigerating machine comprises a conduction passage 14d, a circulation passage 21 and a check valve 22 for circulating the fluid in a butter tank 16 to the low pressure side 14c of a compression work chamber to produce a very small steady flow of working fluid in a pulse tube 13, and a precooling/refrigerating means 30 coupled with a cold accumulator 12 in a specified direction of the steady flow to discharge heat imparted from the steady flow to the cold accumulator 12 at a specified position in the direction of steady flow from the cold accumulator 12.



CLAIMS

[Claim(s)]
[Claim 1]Regenerator with which a working fluid was filled up.
Pulse pipes which are open for free passage to regenerator.
A buffer tank which has a piston in a compression workroom which is open for free passage to regenerator, and opens a working fluid in regenerator for free passage to said pulse pipes via compression, a fluid-drive means expanded and displaced, and a small tube which has a restriction passage by the high-tension side of said compression workroom with this piston.
Are the pulse tube refrigerator provided with the above, and a fluid in said buffer tank is refluxed to the low-tension side of said compression workroom, While forming a circulation means to produce a very small steady flow of said working fluid, in said regenerator and pulse pipes through said piston, It was connected to said regenerator in a prescribed position of a flow direction of said steady flow, and a pre-cooling refrigeration means to which heat given to said regenerator by said steady flow is made to emit from said regenerator in said prescribed position was established.

[Claim 2]The pulse tube refrigerator comprising according to claim 1:
A communicating path formed in said piston so that said circulation means might make the high-tension side and the low-tension side of said compression workroom open for free passage.
A check valve which is provided in a reflux passage which refluxes a fluid in said buffer tank to the low-tension side of said compression workroom, and said communicating path, permits a flow from said low-tension side to the high-tension side, and prevents this and a reverse direction flow.

[Claim 3]The pulse tube refrigerator according to claim 1, wherein said pre-cooling refrigeration means makes heat which has the heat bridge member connected to said regenerator in said prescribed position, and was given to said regenerator by the upstream from said prescribed position by said steady flow emit from said regenerator via this heat bridge member.
[Claim 4]Regenerator with which a working fluid was filled up.
Pulse pipes which are open for free passage to regenerator.
A buffer tank which has a piston in a compression workroom which is open for free passage to regenerator, and opens a working fluid in regenerator for free passage to said pulse pipes via compression, a fluid-drive means expanded and displaced, and a small tube which has a restriction passage by the high-tension side of said compression workroom with this piston.
Are the pulse tube refrigerator provided with the above, and a fluid in said buffer tank is refluxed to the low-tension side of said compression workroom, While forming a circulation means to produce a very small steady flow of said working fluid, in said regenerator and pulse pipes through said piston, Said regenerator is constituted from the 1st regenerator and the 2nd

regenerator which adjoin a flow direction of said steady flow, and it was made for a cross-section area of this 1st regenerator to become larger than a cross-section area of the 2nd regenerator in direction crossing at a right angle to a flow direction of said steady flow.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the pulse tube refrigerator used as a cooling system of the device which operates at the low temperature of a pulse tube refrigerator, especially an infrared sensor, a high-temperature superconductivity device, etc., etc.
[0002]
[Description of the Prior Art]Although the Sterling refrigerator was conventionally used, for example as a cooling system of the device which operates at the low temperature of a high-temperature superconductivity device etc., since there was inconvenience that prolonged operation with a complicated structure was difficult, the pulse tube refrigerator attracts attention as a simple freezer of the structure replaced with it.
[0003]This pulse tube refrigerator is a cycle freezer of the cool storage type which comprised the regenerator and pulse pipes which were provided in the vacuum insulated vessel, and outside of a vacuum insulated vessel including the compressor which applies periodic pressure fluctuation to said working fluid of the cool storage inside of a plane.
By the low-temperature head installed in the low temperature end of pulse pipes within the vacuum insulated vessel, things (an infrared sensor, a high-temperature superconductivity device, etc.) to be cooled are cooled.
A buffer tank is specifically connected to the high temperature end of pulse pipes via an orifice, for example, By giving displacement (in the heat acoustic theory, called the progressive wave ingredient) of the gas which does not contribute to compression and expansion of the working fluid (gas) in pulse pipes, the orifice type pulse tube refrigerator which promoted the heat transfer is also known. This orifice type receives the pressure vibration (compression and expansion) of the high pressure gas inside pulse pipes, The phase contrast of displacement of the gas can be controlled by an orifice, and bigger refrigerating capacity than what is called a BASIC type can be expected by making displacement of the progressive wave ingredient which does not participate in said pressure fluctuation by this increase.
[0004]As shown in drawing 5, while forming the passage 6 which bypasses the regenerator 2 and the pulse pipes 3 between the delivery of the compressor 1, and the high temperature end part 3a of the pulse pipes 3, There is also a pulse tube refrigerator called what is called a double inlet type that adjusted the grade of the diaphragm of the passage 6 by the valve 7 provided in this passage 6. the gas filled up with the this double inlet type pulse tube refrigerator into the inside of the regenerator 2 and the pulse pipes 3 -- compression [from both sides] - it is expanded and displaced. By adjusting the opening of the valve 7, the amplitude of gas displacement can be optimized and refrigerating capacity can be heightened.
[0005]
[Problem(s) to be Solved by the Invention]An above-mentioned pulse tube refrigerator is cooled by the almost same principle as a Sterling refrigerator. Specifically, the gas of the low

temperature end of pulse pipes is understood to operate just like the low temperature side piston of a Sterling refrigerator. However, since it is being fixed to the same shaft as a compression piston in the sterling organization, the regeneration of power is possible for the power of the piston by the side of low temperature, but in a pulse tube refrigerator, since it is throwing away as heat from the orifice etc., there is a problem that refrigerating capacity and efficiency are theoretically inferior.

[0006]This invention is made that the problem that this refrigerating capacity and efficiency are inferior should be solved.

[0007]

[Means for Solving the Problem]In order to solve the above-mentioned technical problem, the 1st invention, Regenerator with which a working fluid (gas) was filled up, and pulse pipes which are open for free passage to regenerator, Have a compression workroom which is open for free passage to regenerator, and a working fluid in regenerator by capacity change of this compression workroom Compression and a fluid-drive means expanded and displaced, A buffer tank which is open for free passage to said pulse pipes via a small tube which has a restriction passage, While forming a circulation means to be a ******** pulse tube refrigerator, to reflux a fluid in said buffer tank to the low-tension side of said compression workroom, and to produce a very small steady flow of said working fluid in said regenerator and pulse pipes, It was connected to said regenerator in a prescribed position of a flow direction of said steady flow, and a pre-cooling refrigeration means to which heat given to said regenerator by said steady flow is made to emit from said regenerator in said prescribed position was established.

[0008]In this invention, a continuous chilling effect of a low temperature end part is acquired in a working fluid (henceforth a gas) in pulse pipes compression and by making it expanded and displaced, carrying heat by the side of a low temperature end part of pulse pipes to the high temperature end part side, and removing that heat in a high temperature end part. Since an inside of regenerator and pulse pipes is made to produce a steady flow with a very late flow which goes to the pulse-pipes side from the regenerator side by a circulation means at this time, a heat flow which goes from a high place of temperature to the lower one, i.e., the low temperature end side, within regenerator arises, but. Gaseous mean temperature in the state of being mostly in agreement with a tube wall of regenerator and pulse pipes. In a pre-cooling position of regenerator by a pre-cooling refrigeration means, most quantity of heat is removed among heat which a gas emits to regenerator, and the same operation is produced as a steady flow produced refrigerating capacity only for said removed quantity of heat by a low temperature end of regenerator by this. Thus, since it can fully control and refrigerating capacity on appearance in a low temperature end can be produced by another refrigeration means of a pre-cooling refrigeration means by pre-cooling unnecessary heat flow rate ON by the side of a low temperature end of regenerator from a low temperature end in a hot prescribed position, It contributes to improvement in cooling efficiency of a freezer decided only by exhaust heat temperature and endothermic temperature greatly.

[0009]A communicating path formed in said piston so that said circulation means might make the high-tension side and the low-tension side of said compression workroom open for free passage, It is preferred to have a reflux passage which refluxes a fluid in said buffer tank to the low-tension side of said compression workroom, and a check valve which is provided in said communicating path, permits a flow from said low-tension side to the high-tension side, and prevents this and a reverse direction flow. If it is made such, composition is simple and a durable circulation means can be realized to low cost.

[0010]Said pre-cooling refrigeration means has the heat bridge member connected to said regenerator in said prescribed position, If it is made to make heat given to said regenerator by the upstream from said prescribed position by said steady flow emit from said regenerator via this heat bridge member, only by setting up suitably a connecting location of a heat bridge member in a flow direction of a steady flow, It can respond to a freezer of many specifications by

the same pre-cooling refrigeration means.
[0011]Pulse pipes which the 2nd invention opens for free passage to regenerator with which a working fluid was filled up, and regenerator, In a compression workroom which is open for free passage to regenerator, have a piston and a working fluid in regenerator by the high-tension side of said compression workroom with this piston Compression and a fluid-drive means expanded and displaced, A buffer tank which is open for free passage to said pulse pipes via a small tube which has a restriction passage, Are a ******** pulse tube refrigerator and a fluid in said buffer tank is refluxed to the low-tension side of said compression workroom, While forming a circulation means to produce a very small steady flow of said working fluid, in said regenerator and pulse pipes through said piston, Said regenerator is constituted from the 1st regenerator and the 2nd regenerator which adjoin a flow direction of said steady flow, and it was made for a cross-section area of this 1st regenerator to become larger than a cross-section area of the 2nd regenerator in direction crossing at a right angle to a flow direction of said steady flow.
[0012]If it does in this way, since cool storage capability of the 1st regenerator will become larger than the 2nd regenerator, in the state where the amount of heat flow rate ON by a steady flow and a refrigerating capacity difference by a difference of the cool storage capability balance. The same effect can be acquired as the 1st regenerator and the 2nd regenerator performed pre-cooling by the above-mentioned pre-cooling refrigeration means in a ****** prescribed position.
[0013]
[Embodiment of the Invention]Hereafter, an embodiment of the invention is described based on an accompanying drawing. Drawing 1 is a figure showing one embodiment of the pulse tube refrigerator concerning the 1st invention, and shows the example which applied this invention to the superconductivity filter system. In the figure, 11 is a vacuum insulated vessel and the regenerator 12 which has two or more fluid channels (not shown for details) inside, the pulse pipes 13 connected with the regenerator 12 via the low temperature part which is not illustrated, and ** are stored by the vacuum insulated vessel 11. the regenerator 12 consists of stainless steel, copper, or a copper alloy in a cylindrical casing -- many -- although the cold reserving material of the plate shape of several sheets is laminated and many (plurality) fluid channels of a book are formed by the hole formed in the cold reserving material, respectively, what stored many granular cold reserving materials may be used. [many]
[0014]The fluid channel of the regenerator 12 and the building envelope of the pulse pipes 13 are open for free passage so that one working clearance may be formed, and it fills up with predetermined working fluids (for example, inactive gas, specifically helium, argon, or nitrogen etc.) in this working clearance. Said fluid channel of the regenerator 12 is open for free passage to the high-tension-side workroom 14b (high-tension side of a compression workroom) of the piston type compressor 14 (fluid-drive means) established in the exterior of the vacuum insulated vessel 11, the piston 14a of this compressor 14 passes the regenerator 12 -- said working fluid -- periodic -- compression - you make it expanded and displaced compressing and expanding a working fluid here, Periodic pressure variation is applied to working fluid, and the volume is periodically changed to it (if it sees about minute space). What the fluid displacement of pressure variation and an ingredient in phase added periodically produces is said, and what displacing a working fluid only moves working fluid for to the shaft orientations of the pulse pipes 13 (the fluid displacement which does not participate in compression and expansion of a working fluid, and from which pressure variation and a phase differ arises) is said.
[0015]The regenerator 12 absorbs the heat of a working fluid at the time of compression of a working fluid, functions as carrying out isothermal compression of the working fluid, on the other hand, gives the heat accumulated at the time of expansion of a working fluid to a working fluid, and functions as carrying out isothermal expansion of the working fluid. Said low temperature part between the regenerator 12 and the pulse pipes 13 constitutes what is called a cold head, and the predetermined thing attached to this low temperature part to be cooled, for example,

two or more superconductivity filters installed in the surroundings of the pulse pipes 13 by the hoop direction prescribed interval, is cooled. A superconductivity filter is used as a band pass filter, in order to receive the feeble radio wave received with the antenna, for example in the base station of a mobile communication system. Of course, it may be a filter module containing a low noise amplifier.

[0016]The pulse pipes 13 are formed in the end aperture shape which carries out an opening by the regenerator 12 side by the metal pipes of the thin meat which consists of stainless steel, titanium, etc., for example, and an internal working fluid (gas) works like a piston by the low temperature end side of the regenerator 12. It is connected to the buffer tank 16 via the small tube 15 which has the orifice 15a (restriction passage), and the pulse pipes 13 radiate heat by the high temperature end side of the pulse pipes 13 with this small tube 15.

[0017]The buffer tank 16 can be open for free passage via the reflux passage 21 used as a restriction passage to the low-tension side workroom 14c (low-tension side of a compression workroom) of the compressor 14, and can reflux a working fluid now from the buffer tank 16 to the low-tension side workroom 14c of the compressor 14. It is equipped with the check valve 22 which permits the flow from the low-tension side workroom 14c to the high-tension-side workroom 14b, and prevents the flow of this and an opposite direction while 14 d of communicating paths are formed in the piston 14a of the compressor 14. 14 d of these communicating paths, the reflux passage 21, and the check valve 22 constitute a circulation means to produce the very small steady flow of a working fluid in the regenerator 12 and the pulse pipes 13.

[0018]In the prescribed position of the flow direction of said steady flow, were connected to the regenerator 12, for example, 31 is a copper heat bridge member. This heat bridge member 31 is a member of the high heat conductivity for making the heat given to the regenerator 12 by the upstream from said prescribed position by the steady flow of said working fluid emit from the regenerator 12, It is connected to the low temperature part 30a of the pre-cooling freezer 30 so that the heat given to the regenerator 12 by the upstream from said prescribed position by said steady flow may be made to emit from the regenerator 12. The compressor 34 with which this pre-cooling freezer 30 has the piston 34a which reciprocates, for example on predetermined frequency, The regenerator 32 connected to the compressor 34 by one end, and the pulse pipes 33 of the tip blockade shape connected to the other end of the regenerator 32, It is the orifice type thing provided with the small tube 35 connected to the high temperature end of the pulse pipes 33, and the buffer tank 37 which is open for free passage to the pulse pipes 33 via the restriction passage in this small tube 35.

[0019]Next, operation of this pulse tube refrigerator is explained. first -- the compressor 14 drives -- the high-pressure working fluid (gas) in the regenerator 12 and the pulse pipes 13 -- the number of prescribed cycles -- compression - it being expanded and displaced and, While the working fluid of the inside carries the heat by the side of the low temperature end part of the pulse pipes 13 to the high temperature end part side, a fixed temperature gradient is formed in the inside of the pulse pipes 13.

[0020]On this state and in the inside of the regenerator 12 and the pulse pipes 13, Since the mean temperature of a working fluid (gas) is mostly in agreement with each inner wall temperature of the regenerator 12 and the pulse pipes 13, The gas which flowed into the regenerator 12 from the compressor 14 gives heat to the regenerator 12 until it reaches a low temperature part, and when this gas comes out of the low temperature end of the regenerator 12 and goes to the high temperature end of the pulse pipes 13, this gas takes heat from the tube wall of the pulse pipes 13.

[0021]Therefore, as shown in the drawing 2 upper part, the temperature of this gas decreases gradually within the regenerator 12 from inlet temperature Ta (room temperature in a vacuum insulated vessel) of the regenerator 12, falls to cooling temperature Tc of a low temperature part, and rises gradually from there to the high temperature end of the pulse pipes 13. In this state, as

shown in the figure bottom, it decreases gradually within the regenerator 12, and by a low temperature part, gaseous internal energy becomes the minimum and increases from there gradually to the high temperature end of the pulse pipes 13. If this system assumes that it is completely reversible, even if a steady flow passes the inside of the pulse pipes 13, gaseous internal energy will become the same by the high temperature end of the regenerator 12, and the high temperature end of the pulse pipes 13. In the figure, Tb is low temperature from room temperature Ta in the vacuum insulated vessel 11, and is the pre-cooling position temperature (temperature of a prescribed position) of an elevated temperature [Tc / low temperature part temperature].

[0022]If it considers that heat flows into the lower one from the high place of temperature in the regenerator 12, as for the quantity of heat of the heat which the gas threw away into the regenerator 12, the downstream (low temperature end side) will become large up to said prescribed position. In this state, as gas temperature is the prescribed position 12 used as Tb, i.e., regenerator, the heat for quantity-of-heat Q 1 minute is emitted by pre-cooling through the heat bridge member 31 of the pre-cooling freezer 30. Therefore, a steady flow will produce the refrigerating capacity of the quantity of heat Q1 by the low temperature end of the regenerator 12 seemingly, and refrigerating capacity will increase only the part. If it puts in another way, the heat emitted to the regenerator 12 from the gas can be efficiently taken out from said prescribed position outside by the upstream by the steady flow in the regenerator 12 in said prescribed position where the gas serves as temperature Tb. Therefore, performing only the heat transfer from the low temperature end side of the pulse pipes 13 to the high temperature end side, the heat flow rate ON to a low temperature part can be held down to the quantity of heat Q2 smaller enough than the quantity of heat Q1, and refrigerating capacity can be raised substantially.

[0023]Thus, the inside of the regenerator 12 and the pulse pipes 13 is made to produce the steady flow with a very late flow which goes to the pulse-pipes 13 side from the regenerator 12 side by a circulation means in this invention, The gaseous mean temperature in the state of being mostly in agreement with the tube wall of the regenerator 12 and the pulse pipes 13. Heat is given to the regenerator 12 until the gas which flowed into the regenerator 12 from the compressor 14 side reaches a low temperature part, Take heat from the tube wall of the pulse pipes 13 until the gas which came out of the low temperature part reaches the high temperature end of the pulse pipes 13, and also most quantity of heat Q1 is made to emit certainly in the pre-cooling position by the pre-cooling freezer 30 among the heat which the gas emitted to the regenerator 12, and it removes. Thus, since the same operation as the steady flow produced the refrigerating capacity only for the quantity of heat which carried out account removal of the kickback is carried out, Pre-cooling in the prescribed position where temperature is higher than a low temperature part can raise the refrigerating capacity of a pulse tube refrigerator easily, and the cooling efficiency of the freezer decided only by exhaust heat temperature and endothermic temperature can be raised easily and substantially.

[0024]In addition, the reflux passage which forms a communicating path in a piston so that the high-tension side and the low-tension side of a compression workroom may be made to open for free passage, and refluxes the fluid in said buffer tank to the low-tension side of a compression workroom, If the check valve which permits the flow from the low-tension side to the high-tension side in said communicating path, and prevents the flow of this and an opposite direction is provided, composition is simple and a durable circulation means can be realized to low cost.

[0025]In this embodiment, the pre-cooling freezer 30 has the heat bridge member 31 connected to the regenerator 12 in said prescribed position, Since he is trying to make the heat given to the regenerator 12 by the upstream from said prescribed position by said steady flow emit from the regenerator 12 via the heat bridge member 31, Only by setting up suitably the connecting location of the heat bridge member 31 in the flow direction of a steady flow, it can respond to the freezer of many specifications by the same pre-cooling refrigeration means 30.

[0026]In an above-mentioned embodiment, although two compressors were formed, it cannot be overemphasized that it can drive with one compressor. Drawing 3 is a figure showing one embodiment of the pulse tube refrigerator concerning the 2nd invention. In this embodiment, the regenerator 50 consists of the 1st regenerator 51 and the 2nd regenerator 52 which adjoin the flow direction of said steady flow, and the cross-section area of that 1st regenerator 51 is large only predetermined magnification from the cross-section area of the 2nd regenerator 52 in the direction crossing at a right angle (diameter direction) to the flow direction of said steady flow.
[0027]Therefore, assumption of the phase of ideal regenerator, a pressure, and gas displacement will obtain the heat transport amount mostly proportional to a cross-section area in the regenerators 51 and 52. If there is no steady flow, as for a temperature gradient, the direction of the regenerator 52 will become large. If it can design so that the difference of the refrigerating capacity between the amount of heat flow rate ON by a steady flow and the regenerators 51 and 52 may balance, the same effect as the above-mentioned example using two freezers will be acquired. However, actually, since the phase of a pressure and gas displacement is not ideal, efficiency falls somewhat.
[0028]Although the piston 14a was equipped with the check valve 22 (check valve) in the above-mentioned embodiment, As it replaces with this and it is shown in drawing 4 (a), and the communicating path of the piston 14a is made into the communicating path 14e (circulation means) with a moderate diaphragm function or is shown in drawing 4 (b), It may be made to attach the piping 61 (circulation means) with orifice 62 which makes it the shape which divides thoroughly the compression workrooms 14b and 14c of the high-tension side and the low-tension side which do not have a communicating path in the piston 14a of the compressor 14, and opens both the compression workrooms 14b and 14c for free passage to the case of the compressor 14.
[0029]The circulating flow (steady flow) which a double inlet type etc. may be sufficient as and happens carries out the function replaced with a check valve in these cases sure enough, and it is **. This steady flow is caused by the acoustic-inertance style etc., and this acoustic-inertance style is known as a typical nonlinear sound phenomenon. If a certain phenomenon is ready, even if there is no check valve, a uni directional flow as shown in drawing 4 (a) and drawing 4 (b), respectively will happen, and the free passage 14e with the diaphragm function allotted to the piston, and the piping 61 and the orifice 62 will control the mass.
[0030]
[Effect of the Invention]As mentioned above, while forming a circulation means to produce the very small steady flow of a working fluid, in regenerator and pulse pipes according to the 1st invention, Since the pre-cooling refrigeration means to which the heat given to regenerator by said steady flow in the prescribed position of the flow direction of a steady flow is made to emit from regenerator is established, While pre-cooling removes most quantity of heat from a low temperature part easily in a hot prescribed position among the heat which a gas emits to regenerator, The operation same with producing the refrigerating capacity only for said removed quantity of heat by the low temperature end of regenerator by a steady flow can be carried out, and it can contribute to improvement in the cooling efficiency of the freezer decided only by exhaust heat temperature and endothermic temperature greatly.
[0031]The reflux passage which forms a communicating path in a piston so that the high-tension side and the low-tension side of said compression workroom may be made to open for free passage, and refluxes the fluid in said buffer tank to the low-tension side of a compression workroom, If the check valve which permits the flow from the low-tension side to the high-tension side in said communicating path, and prevents the flow of this and an opposite direction is provided, composition is simple and a durable circulation means can be realized to low cost.
[0032]Said pre-cooling refrigeration means has the heat bridge member connected to said regenerator in said prescribed position, If it is made to make the heat given to said regenerator

by the upstream from said prescribed position by said steady flow emit from said regenerator via this heat bridge member, only by setting up suitably the connecting location of the heat bridge member in the flow direction of a steady flow, It can respond to the freezer of many specifications by the same pre-cooling refrigeration means.

[0033]According to the 2nd invention, said regenerator is constituted from the 1st regenerator and the 2nd regenerator which adjoin the flow direction of said steady flow, Since he is trying for the cross-section area of this 1st regenerator to become larger than the cross-section area of the 2nd regenerator in the direction crossing at a right angle to the flow direction of said steady flow, In the state where the amount of heat flow rate ON by a steady flow and the refrigerating capacity difference by the difference of the cool storage capability balance, the effect same, with having performed pre-cooling by the above-mentioned pre-cooling refrigeration means can be acquired, as a result it is high refrigerating capacity and can be considered as a compact pulse tube refrigerator.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is the outline lineblock diagram showing one embodiment of the pulse tube refrigerator concerning the 1st invention.
[Drawing 2]It is a graph which shows the influence of the internal energy change and pulse pipes on a steady flow in one embodiment.
[Drawing 3]It is the outline lineblock diagram showing one embodiment of the pulse tube refrigerator concerning the 2nd invention.
[Drawing 4]the pulse tube refrigerator which (a) is the important section lineblock diagram showing other embodiments of the pulse tube refrigerator concerning the 2nd invention, and (b) requires for the 2nd invention -- being the further -- others -- it is the important section lineblock diagram showing an embodiment.
[Drawing 5]It is an outline lineblock diagram of a conventional double inlet type pulse tube refrigerator.
[Description of Notations]
11 Vacuum insulated vessel
12 Regenerator
13 Pulse pipes
14 Compressor (fluid-drive means)
14b High-tension-side workroom (high-tension side of a compression workroom)
14c Low-tension side workroom (low-tension side of a compression workroom)
14d and 14e Communicating path (circulation means)
15 Small tube
15a Orifice (restriction passage)
16 Buffer tank
21 Reflux passage (circulation means)
22 Check valve (circulation means)
30 Pre-cooling freezer (pre-cooling refrigeration ****)
30a Low temperature part
31 Heat bridge member
50 Regenerator
51 The 1st regenerator
52 The 2nd regenerator
61 Piping (circulation means)
62 Orifice (circulation means)

[Translation done.]

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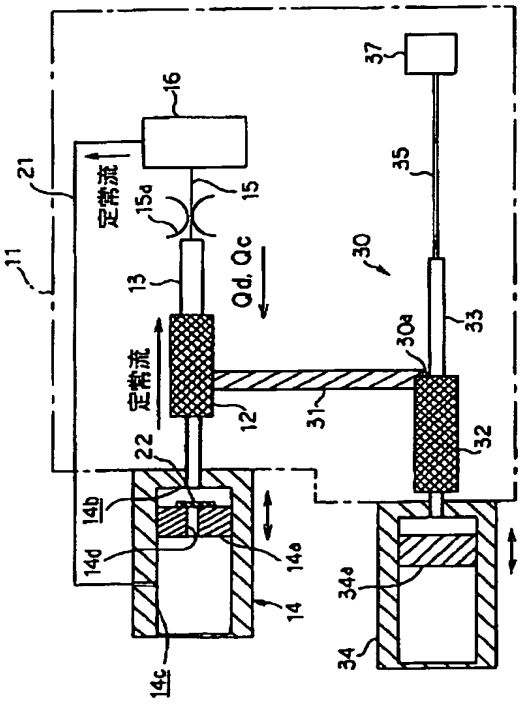
(54)【発明の名称】　パルス管冷凍機

(57)【要約】

【課題】　蓄冷器内の熱移動による低温部への不要な熱流入を低減することにより、冷凍能力に優れた小型・軽量かつ構成の簡素なパルス管冷凍機を提供する。

【解決手段】　バッファタンク16内の流体を圧縮作業室の低圧側14ｃに還流させ、蓄冷器12およびパルス管13内に作動流体の微少な定常流を生じさせる循環手段14ｃ，21，22を設けるとともに、定常流の流れ方向の所定位置で蓄冷器12に接続され、定常流により蓄冷器12に与えられた熱を前記所定位置で蓄冷器12から放出させる予冷冷凍手段30を設けている。



1

【特許請求の範囲】

【請求項１】作動流体が充填された蓄冷器と、蓄冷器に連通するバルス管と、蓄冷器に連通する圧縮作業室内にピストンを有し該ピストンにより前記圧縮作業室の高圧側で蓄冷器内の作動流体を圧縮・膨張および変位させる流体駆動手段と、絞り通路を有する細管を介して前記バルス管に連通するバッファタンクと、を備えたバルス管冷凍機であって、

前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させ、前記ピストンを通して前記蓄冷器およびバルス管内に前記作動流体の微少な定常流を生じさせる循環手段を設けるとともに、

前記定常流の流れ方向の所定位置で前記蓄冷器に接続され、前記定常流により前記蓄冷器に与えられた熱を前記所定位置で前記蓄冷器から放出させる予冷冷凍手段を設けたことを特徴とするバルス管冷凍機。

【請求項２】前記循環手段が、前記圧縮作業室の高圧側と低圧側を連通させるよう前記ピストンに形成された連通路と、前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させる還流通路と、前記連通路に設けられ前記低圧側から高圧側への流れを許容しこれと逆方向の流れを阻止する逆止弁と、を有することを特徴とする請求項１に記載のバルス管冷凍機。

【請求項３】前記予冷冷凍手段が、前記所定位置で前記蓄冷器に接続された熱ブリッジ部材を有し、前記定常流により前記所定位置より上流側で前記蓄冷器に与えられた熱を、該熱ブリッジ部材を介して前記蓄冷器から放出させることを特徴とする請求項１に記載のバルス管冷凍機。

【請求項４】作動流体が充填された蓄冷器と、蓄冷器に連通するバルス管と、蓄冷器に連通する圧縮作業室内にピストンを有し該ピストンにより前記圧縮作業室の高圧側で蓄冷器内の作動流体を圧縮・膨張および変位させる流体駆動手段と、絞り通路を有する細管を介して前記バルス管に連通するバッファタンクと、を備えたバルス管冷凍機であって、

前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させ、前記ピストンを通して前記蓄冷器およびバルス管内に前記作動流体の微少な定常流を生じさせる循環手段を設けるとともに、

前記蓄冷器を、前記定常流の流れ方向に隣接する第１蓄冷器および第２蓄冷器から構成し、前記定常流の流れ方向に対する直交方向で該第１蓄冷器の断面積が第２蓄冷器の断面積より大きくなるようにしたことを特徴とするバルス管冷凍機。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、バルス管冷凍機、特に赤外線センサや高温超伝導デバイス等の低温で動作するデバイスの冷却装置として用いられるバルス管冷凍機に関する。

2

【０００２】

【従来の技術】従来、高温超伝導デバイス等の低温で動作するデバイスの冷却装置として、例えばスターリング冷凍機が用いられていたが、構造が複雑で長時間の運転が難しいという不都合があったため、それに代わる構造の簡素な冷凍機としてバルス管冷凍機が注目されている。

【０００３】このバルス管冷凍機は、真空断熱容器内に設けた蓄冷器およびバルス管と、真空断熱容器外から前記蓄冷機内の作動流体に周期的な圧力変動を加える圧縮機とを含んで構成された蓄冷式のサイクル冷凍機であり、真空断熱容器内でバルス管の低温端に設置した低温ヘッドにより、被冷却物（赤外線センサや高温超伝導デバイス等）を冷却するようになっている。具体的には、例えばバルス管の高温端にオリフィスを介してバッファタンクを接続し、バルス管内の作動流体（ガス）の圧縮・膨張に寄与しないガスの変位（熱音響理論などでは進行波成分とよばれている）を与えることによって、熱移送を促進するようにしたオリフィス型バルス管冷凍機も知られている。このオリフィス型は、バルス管内部の高圧ガスの圧力振動（圧縮・膨張）に対し、オリフィスによってそのガスの変位の位相差を制御することができ、これによって前記圧力変動に関与しない進行波成分の変位を増加させることで、いわゆるｂａｓｉｃ型よりも大きな冷凍能力が期待できる。

【０００４】さらに、図５に示すように、圧縮機１の吐出口とバルス管３の高温端部３ａとの間に蓄冷器２およびバルス管３をバイパスする通路６を設けるとともに、この通路６に設けたバルブ７によって通路６の絞りの程度を調節するようにした、いわゆるダブルインレット型と呼ばれるバルス管冷凍機もある。このダブルインレット型のバルス管冷凍機では、蓄冷器２およびバルス管３の内部に充填されたガスが両側から圧縮・膨張および変位させられる。また、バルブ７の開度を調節することで、ガス変位の振幅を最適化し、冷凍能力を高めることができる。

【０００５】

【発明が解決しようとする課題】上述のバルス管冷凍機はスターリング冷凍機とほぼ同様な原理で冷却される。具体的には、バルス管の低温端の気体があたかもスターリング冷凍機の低温側ピストンのように動作すると理解されている。しかしながら、低温側のピストンの動力はスターリング機関では圧縮ピストンと同じシャフトに固定されているために動力の回生が可能であるが、バルス管冷凍機ではオリフィス等から熱として捨てているために原理的に冷凍能力及び効率が劣るという問題がある。

【０００６】本発明は、かかる冷凍能力及び効率が劣るという問題を解消すべくなされたものである。

【０００７】

【課題を解決するための手段】上記の課題を解決するために、第１の発明は、作動流体（気体）が充填された蓄冷器と、蓄冷器に連通するバルス管と、蓄冷器に連通する圧縮作業室を有し該圧縮作業室の容積変化により蓄冷器内の作動流体を圧縮・膨張および変位させる流体駆動手段と、絞り通路を有する細管を介して前記バルス管に連通するバッファタンクと、を備えたバルス管冷凍機であって、前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させ、前記蓄冷器およびバルス管内に前記作動流体の微少な定常流を生じさせる循環手段を設けるとともに、前記定常流の流れ方向の所定位置で前記蓄冷器に接続され、前記定常流により前記蓄冷器に与えられた熱を前記所定位置で前記蓄冷器から放出させる予冷冷凍手段を設けたことを特徴とする。

【０００８】この発明では、バルス管内の作動流体（以下、気体という）を圧縮・膨張および変位させてバルス管の低温端部側の熱を高温端部側に運び、高温端部でその熱を除去することにより、低温端部の連続的な冷却効果が得られる。このとき、循環手段によって、蓄冷器およびバルス管の内部に蓄冷器側からバルス管側に向かう極めて流れの遅い定常流を生じさせているので、蓄冷器内で温度の高いところから低い方、すなわち低温端側に向かう熱の流れが生じるが、気体の平均温度が蓄冷器およびバルス管の管壁とほぼ一致する状態で、気体が蓄冷器に放出する熱のうち大半の熱量が予冷冷凍手段による蓄冷器の予冷位置において除去され、これによって定常流が蓄冷器の低温端で前記除去した熱量分だけの冷凍能力を生み出したのと同様な作用を生じる。このように、予冷冷凍手段という別の冷凍手段によって、蓄冷器の低温端側への不要な熱流入を低温端より高温の所定位置で予冷することによって十分に抑制し、低温端での見かけ上の冷凍能力を生み出すことができるので、排熱温度と吸熱温度だけで決まる冷凍機の冷却効率の向上に大きく寄与するものとなる。

【０００９】前記循環手段は、前記圧縮作業室の高圧側と低圧側を連通させるよう前記ピストンに形成された連通路と、前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させる還流通路と、前記連通路に設けられ前記低圧側から高圧側への流れを許容しこれと逆方向の流れを阻止する逆止弁と、を有するのが好ましい。そのようにすると、構成が簡素で耐久性のある循環手段を低コストに実現することができる。

【００１０】また、前記予冷冷凍手段が、前記所定位置で前記蓄冷器に接続された熱ブリッジ部材を有し、前記定常流により前記所定位置より上流側で前記蓄冷器に与えられた熱を、該熱ブリッジ部材を介して前記蓄冷器から放出させるようにすると、定常流の流れ方向における熱ブリッジ部材の接続位置を適宜設定するだけで、同一の予冷冷凍手段により多仕様の冷凍機に対応することができる。

【００１１】さらに、第２の発明は、作動流体が充填された蓄冷器と、蓄冷器に連通するバルス管と、蓄冷器に連通する圧縮作業室内にピストンを有し該ピストンにより前記圧縮作業室の高圧側で蓄冷器内の作動流体を圧縮・膨張および変位させる流体駆動手段と、絞り通路を有する細管を介して前記バルス管に連通するバッファタンクと、を備えたバルス管冷凍機であって、前記バッファタンク内の流体を前記圧縮作業室の低圧側に還流させ、前記ピストンを通して前記蓄冷器およびバルス管内に前記作動流体の微少な定常流を生じさせる循環手段を設けるとともに、前記蓄冷器を、前記定常流の流れ方向に隣接する第１蓄冷器および第２蓄冷器から構成し、前記定常流の流れ方向に対する直交方向で該第１蓄冷器の断面積が第２蓄冷器の断面積より大きくなるようにしたことを特徴とする。

【００１２】このようにすると、第１蓄冷器の蓄冷能力が第２蓄冷器より大きくなることから、定常流による熱流入量とその蓄冷能力の差による冷凍能力差とがつり合う状態で、第１蓄冷器および第２蓄冷器が隣合う所定位置において上記予冷冷凍手段による予冷を行ったのと同様な効果を得ることができる。

【００１３】

【発明の実施の形態】以下、本発明の実施の形態について添付図面に基づいて説明する。図１は第１の発明に係るバルス管冷凍機の一実施形態を示す図であり、本発明を超伝導フィルタシステムに適用した例を示している。同図において、１１は真空断熱容器であり、真空断熱容器１１には、内部に複数本の流体通路（詳細は図示していない）を有する蓄冷器１２と、図示しない低温部を介して蓄冷器１２に連結されたバルス管１３と、が収納されている。蓄冷器１２は、円筒状のケーシング内に例えばステンレス、銅又は銅合金等からなる多数枚のプレート状の蓄冷材を積層し、その蓄冷材にそれぞれ多数形成された孔によって多数（複数）本の流体通路を形成したものであるが、多数の粒状の蓄冷材を収納したものでもよい。

【００１４】蓄冷器１２の流体通路とバルス管１３の内部空間は、一つの作業空間を形成するように連通しており、この作業空間内に所定の作動流体（例えば不活性ガス、具体的にはヘリウム、アルゴン又は窒素等）が充填されている。蓄冷器１２の前記流体通路は、真空断熱容器１１の外部に設けたピストン型の圧縮機１４（流体駆動手段）の高圧側作業室１４ｂ（圧縮作業室の高圧側）に連通しており、この圧縮機１４のピストン１４ａが蓄冷器１２を介して前記作動流体を周期的に圧縮・膨張および変位させるようになっている。なお、ここで作動流体を圧縮・膨張させるとは、作業流体に周期的な圧力変化を加えて、その体積を周期的に変化させる（微小空間についてみれば、周期的に加わる圧力変化と同位相成分の流体変位が生じる）ことをいい、作動流体を変位させ

るとは、作業流体をパルス管１３の軸方向に単に移動させる（作動流体の圧縮・膨張に関与しない、圧力変化と位相の異なる流体変位が生じる）ことをいう。

【００１５】蓄冷器１２は、作動流体の圧縮時には作動流体の熱を吸収し、作動流体を等温圧縮させるように機能し、一方、作動流体の膨張時には蓄積した熱を作動流体に与えて、作動流体を等温膨張させるように機能する。また、蓄冷器１２とパルス管１３の間の前記低温部はいわゆるコールドヘッドを構成しており、この低温部に取り付けられた所定の被冷却物、例えばパルス管１３の周りに周方向所定間隔に設置された複数の超伝導フィルタが冷却されるようになっている。なお、超伝導フィルタは、例えば移動体通信系の基地局においてアンテナで受けた微弱電波を受信するためにバンドパスフィルタとして使用されるものである。勿論、低雑音増幅器を含むフィルタモジュール等であってもよい。

【００１６】パルス管１３は、例えばステンレス、チタン等からなる薄肉の金属製パイプによって蓄冷器１２側で開口する一端開口形状に形成されており、内部の作動流体（気体）が蓄冷器１２の低温端側でピストンのように働くようになっている。また、パルス管１３はオリフィス１５ａ（絞り通路）を有する細管１５を介してバッファタンク１６に接続されており、この細管１５によりパルス管１３の高温端側で放熱を行うようになっている。

【００１７】また、バッファタンク１６は絞り通路となる還流通路２１を介して圧縮機１４の低圧側作業室１４ｃ（圧縮作業室の低圧側）に連通しており、バッファタンク１６から圧縮機１４の低圧側作業室１４ｃに作動流体を還流させることができるようになっている。さらに、圧縮機１４のピストン１４ａには連通路１４ｄが形成されているとともに、低圧側作業室１４ｃから高圧側作業室１４ｂへの流れを許容しこれと逆方向の流れを阻止する逆止弁２２が装着されている。これら連通路１４ｄ、還流通路２１および逆止弁２２は、蓄冷器１２およびパルス管１３内に作動流体の微少な定常流を生じさせる循環手段を構成している。

【００１８】３１は、前記定常流の流れ方向の所定位置で蓄冷器１２に接続された、例えば銅製の熱ブリッジ部材である。この熱ブリッジ部材３１は、前記作動流体の定常流によって前記所定位置より上流側で蓄冷器１２に与えられた熱を、蓄冷器１２から放出させるための高熱伝導率の部材で、前記定常流により前記所定位置より上流側で蓄冷器１２に与えられた熱を蓄冷器１２から放出させるよう、予冷冷凍機３０の低温部３０ａに接続されている。この予冷冷凍機３０は、例えば所定の周波数で往復動するピストン３４ａを有する圧縮機３４と、一端で圧縮機３４に接続された蓄冷器３２と、蓄冷器３２の他端に接続された先端閉塞形状のパルス管３３と、パルス管３３の高温端に接続された細管３５と、この細管３５内の絞り通路を介してパルス管３３に連通するバッファタンク３７と、を備えたオリフィス型のものである。

【００１９】次に、このパルス管冷凍機の動作について説明する。まず、圧縮機１４が駆動され、蓄冷器１２およびパルス管１３内の高圧の作動流体（気体）が所定サイクル数で圧縮・膨張および変位させられ、その内部の作動流体がパルス管１３の低温端部側の熱を高温端部側へ運ぶとともに、パルス管１３の内部に一定の温度勾配が形成される。

【００２０】この状態においては、蓄冷器１２およびパルス管１３の内部において、作動流体（気体）の平均温度は蓄冷器１２およびパルス管１３のそれぞれの内壁温度とほぼ一致するから、圧縮機１４から蓄冷器１２に流れ込んだ気体は低温部に到達するまでは熱を蓄冷器１２に与えていき、この気体が蓄冷器１２の低温端から出てパルス管１３の高温端に向かうときには、この気体はパルス管１３の管壁から熱を奪っていく。

【００２１】したがって、この気体の温度は、図２の上側に示すように、蓄冷器１２の入口温度Ｔａ（真空断熱容器内の室温）から蓄冷器１２内で徐々に減少して低温部の冷却温度Ｔｃまで下がり、そこからパルス管１３の高温端まで徐々に上昇する。この状態においては、同図の下側に示すように、気体の内部エネルギが蓄冷器１２内で徐々に減少して低温部で最低になり、そこからパルス管１３の高温端まで徐々に増加する。この系が完全に可逆であると仮定すれば、定常流がパルス管１３の内部を通過しても、気体の内部エネルギは蓄冷器１２の高温端とパルス管１３の高温端とで同じになる。なお、同図において、Ｔｂは真空断熱容器１１内の室温Ｔａより低温でかつ低温部温度Ｔｃより高温の予冷位置温度（所定位置の温度）である。

【００２２】また、蓄冷器１２内において温度の高いところから低い方に熱が流れることを考えると、気体が蓄冷器１２に捨てた熱の熱量は、前記所定位置までは下流側（低温端側）ほど大きくなる。この状態において、気体温度がＴｂとなる所定位置、すなわち、蓄冷器１２の途中で、熱量Ｑ１分の熱が熱ブリッジ部材３１を介した予冷冷凍機３０の予冷によって放出される。したがって、定常流が見かけ上は蓄冷器１２の低温端で熱量Ｑ１の冷凍能力を生み出すことになり、その分だけ冷凍能力が高まることになる。換言すれば、蓄冷器１２内の定常流により、前記所定位置より上流側で気体から蓄冷器１２に放出された熱を、その気体が温度Ｔｂとなる前記所定位置で、効率良く外部に取り出すことができることになる。したがって、パルス管１３の低温端側から高温端側への熱移送のみを行いながら、低温部への熱流入を熱量Ｑ１より十分に少ない熱量Ｑ２に抑えることができ、冷凍能力を大幅に向上させることができる。

【００２３】このように、本発明では、循環手段によって、蓄冷器１２およびパルス管１３の内部に蓄冷器１２

側からバルス管１３側に向かう極めて流れの遅い定常流を生じさせ、気体の平均温度が蓄冷器１２およびバルス管１３の管壁とほぼ一致する状態で、圧縮器１４側から蓄冷器１２に流れ込んだ気体が低温部に到達するまで熱を蓄冷器１２に与え、低温部からでた気体がバルス管１３の高温端に達するまでバルス管１３の管壁から熱を奪っていくようにしておき、更に気体が蓄冷器１２に放出した熱のうち大半の熱量Ｑ１を、予冷冷凍機３０による予冷位置において確実に放出させ除去する。このように、定常流が上前記除去した熱量分だけの冷凍能力を生み出したのと同様な作用をさせているので、バルス管冷凍機の冷凍能力を低温部より温度の高い所定位置における予冷によって容易に高めることができ、排熱温度と吸熱温度だけで決まる冷凍機の冷却効率を容易かつ大幅に向上させることができる。

【００２４】これに加えて、圧縮作業室の高圧側と低圧側を連通させるようピストンに連通路を形成し、前記バッファタンク内の流体を圧縮作業室の低圧側に還流させる還流通路と、前記連通路で低圧側から高圧側への流れを許容しこれと逆方向の流れを阻止する逆止弁と、を設けるようにすれば、構成が簡素で耐久性のある循環手段を低コストに実現することができる。

【００２５】また、本実施形態においては、予冷冷凍機３０が、前記所定位置で蓄冷器１２に接続された熱ブリッジ部材３１を有し、前記定常流により前記所定位置より上流側で蓄冷器１２に与えられた熱を、その熱ブリッジ部材３１を介して蓄冷器１２から放出させるようにしているので、定常流の流れ方向における熱ブリッジ部材３１の接続位置を適宜設定するだけで、同一の予冷冷凍手段３０により多仕様の冷凍機に対応することができる。

【００２６】なお、上述の実施形態においては、圧縮機を２つ設けていたが、１つの圧縮機によって駆動することができるのはいうまでもない。図３は、第２の発明に係るバルス管冷凍機の一実施形態を示す図である。この実施形態においては、蓄冷器５０が、前記定常流の流れ方向に隣接する第１蓄冷器５１および第２蓄冷器５２からなり、前記定常流の流れ方向に対する直交方向（径方向）でその第１蓄冷器５１の断面積が第２蓄冷器５２の断面積より所定倍率だけ大きくなっている。

【００２７】したがって、理想的な蓄冷器、かつ、圧力及びガス変位の位相を仮定すると、蓄冷器５１と５２では、断面積にほぼ比例した熱輸送量が得られる。定常流がなければ、温度勾配は蓄冷器５２の方が大きくなる。定常流による熱流入量と蓄冷器５１，５２の間の冷凍能力の差がつり合うように設計できれば、２つの冷凍機を用いた上述例と同様な効果が得られる。ただし、実際には、圧力とガス変位の位相は理想的ではないので、多少効率が落ちる。

【００２８】なお、上述の実施形態では、ピストン１４ａに逆止弁２２（チェック弁）を装着していたが、これに代えて、図４（ａ）に示すように、ピストン１４ａの連通路を適度な絞り機能のある連通路１４ｅ（循環手段）としたり、図４（ｂ）に示すように、圧縮機１４のピストン１４ａを連通路のない高圧側および低圧側の圧縮作業室１４ｂ，１４ｃを完全に仕切る形状にし、かつ、両圧縮作業室１４ｂ，１４ｃを連通するオリフィス６２付きの配管６１（循環手段）を圧縮機１４のケースに付設したりするようにしてもよい。

【００２９】これらの場合、逆止弁に代わる機能をダブルインレット型などでよく起こる循環流（定常流）が果してしる。この定常流は、音響質量流などにより引き起こされるもので、この音響質量流は代表的な非線形音響現象として知られている。ある現象が整えば、逆止弁がなくとも図４（ａ）および図４（ｂ）にそれぞれ示すような一方向流が起こり、その質量はピストンに配した絞り機能をもつ連通１４ｅや、配管６１およびオリフィス６２がコントロールすることになる。

【００３０】

【発明の効果】上述のように、第１の発明によれば、蓄冷器およびバルス管内に作動流体の微少な定常流を生じさせる循環手段を設けるとともに、定常流の流れ方向の所定位置で前記定常流により蓄冷器に与えられた熱を蓄冷器から放出させる予冷冷凍手段を設けているので、気体が蓄冷器に放出する熱のうち大半の熱量を低温部より高温の所定位置で予冷によって容易に除去しながら、定常流によって蓄冷器の低温端で前記除去した熱量分だけの冷凍能力を生み出すのと同様の作用をさせることができ、排熱温度と吸熱温度だけで決まる冷凍機の冷却効率の向上に大きく寄与することができる。

【００３１】また、前記圧縮作業室の高圧側と低圧側を連通させるようピストンに連通路を形成し、前記バッファタンク内の流体を圧縮作業室の低圧側に還流させる還流通路と、前記連通路で低圧側から高圧側への流れを許容しこれと逆方向の流れを阻止する逆止弁と、を設けるようにすれば、構成が簡素で耐久性のある循環手段を低コストに実現することができる。

【００３２】また、前記予冷冷凍手段が、前記所定位置で前記蓄冷器に接続された熱ブリッジ部材を有し、前記定常流により前記所定位置より上流側で前記蓄冷器に与えられた熱を、該熱ブリッジ部材を介して前記蓄冷器から放出させるようにすれば、定常流の流れ方向における熱ブリッジ部材の接続位置を適宜設定するだけで、同一の予冷冷凍手段により多仕様の冷凍機に対応することができる。

【００３３】さらに、第２の発明によれば、前記蓄冷器を、前記定常流の流れ方向に隣接する第１蓄冷器および第２蓄冷器から構成し、前記定常流の流れ方向に対する直交方向で該第１蓄冷器の断面積が第２蓄冷器の断面積より大きくなるようにしているので、定常流による熱流

入量とその蓄冷能力の差による冷凍能力差とがつり合う状態で、上記予冷冷凍手段による予冷を行ったのと同様な効果を得ることができ、その結果、高冷凍能力でかつコンパクトなパルス管冷凍機とすることができる。

【図面の簡単な説明】

【図１】第１の発明に係るパルス管冷凍機の一実施形態を示すその概略構成図である。

【図２】一実施形態における定常流の内部エネルギ変化とパルス管への影響を示すグラフである。

【図３】第２の発明に係るパルス管冷凍機の一実施形態を示すその概略構成図である。

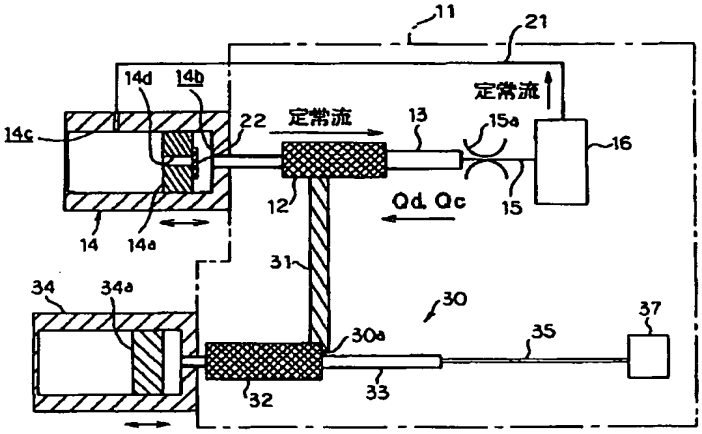
【図４】（ａ）は第２の発明に係るパルス管冷凍機の他の実施形態を示すその要部構成図であり、（ｂ）は第２の発明に係るパルス管冷凍機の更なる他の実施形態を示すその要部構成図である。

【図５】従来のダブルインレット型のパルス管冷凍機の概略構成図である。

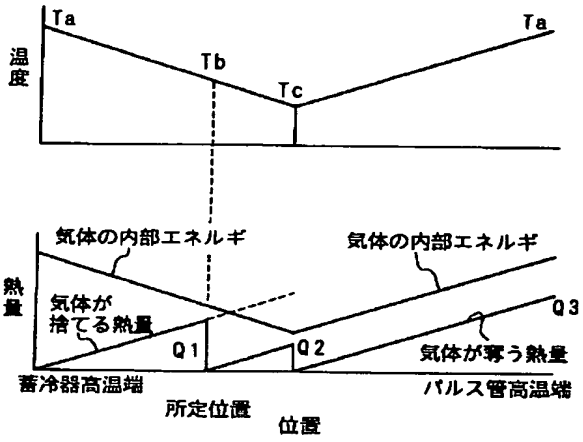
【符号の説明】

１１　真空断熱容器
＊１２　蓄冷器
１３　パルス管
１４　圧縮機（流体駆動手段）
１４ｂ　高圧側作業室（圧縮作業室の高圧側）
１４ｃ　低圧側作業室（圧縮作業室の低圧側）
１４ｄ、１４ｅ　連通路（循環手段）
１５　細管
１５ａ　オリフィス（絞り通路）
１６　バッファタンク
２１　還流通路（循環手段）
２２　逆止弁（循環手段）
３０　予冷冷凍機（予冷冷凍水段）
３０ａ　低温部
３１　熱ブリッジ部材
５０　蓄冷器
５１　第１蓄冷器
５２　第２蓄冷器
６１　配管（循環手段）
＊６２　オリフィス（循環手段）

【図１】

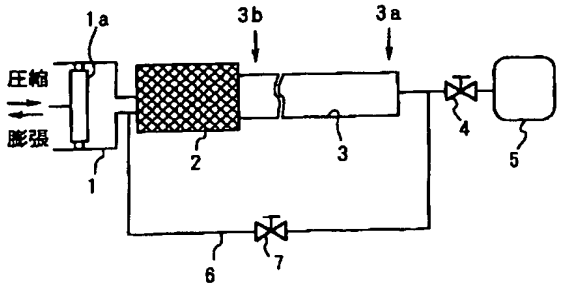


【図２】

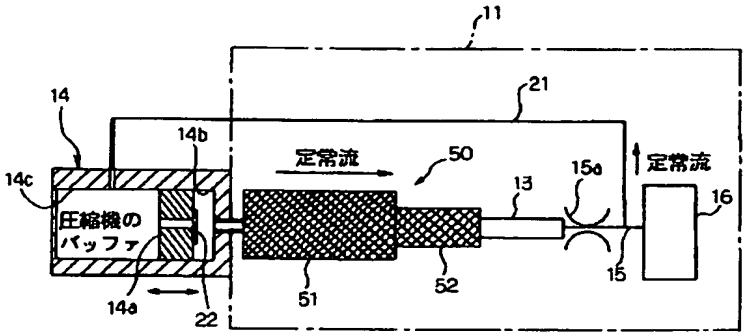


Q1：予冷冷凍機で冷却される熱量
Q2：低温端に流れ込む熱量
Q3：パルス管高温端に排出される熱量

【図５】

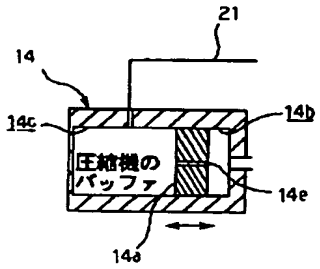


【図３】

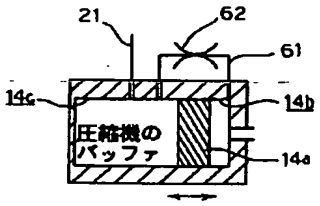

11
14
21
14b
定常流
50
定常流
14c
15a
13
16
圧縮機の
バッファ
14a
22
51
52
15

【図４】

(a)


21
14
14c
14b
圧縮機の
バッファ
14e
14a

(b)


21
62
61
14c
14b
圧縮機の
バッファ
14a